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NERVE ELECTRICAL CONDUCTION, STORAGE AND RETRIEVAL OF INFORMATI--ETC(U)
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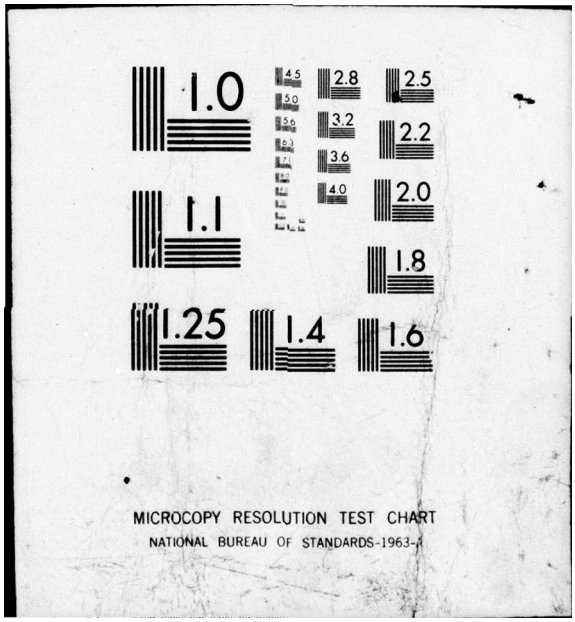
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Report 01901-PMMR

Nerve Electrical Conduction, Storage and Retrieval of Information - A Theory

by

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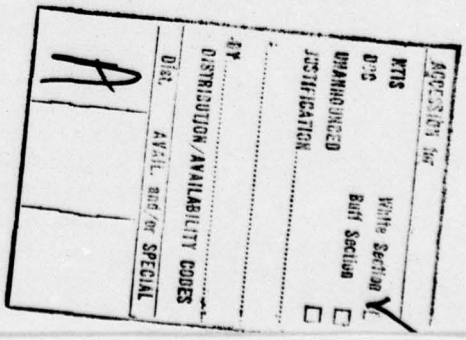
ABSTRACT

Nerve Electrical Conduction Storage and Retrieval of Information

A Theory (1)

Lecithin and cholesterol which form closely packed arrays in the wall of the axon in nerve is identified as the location for electrical conduction, information storage and retrieval. The complex of lecithin and cholesterol is seen as a machine concerned with transporting sodium ions into a corridor comprising two cholesterol molecules. Based on considerations from two approaches, the cholesterol-sodium-cholesterol sandwich becomes superconductive in accordance with Ginzbergs' theory as quantified by Bardeen and co-workers, and electrons tunnel from one sandwich to another.

Hydrated lecithin which is a smectic liquid crystal may become nematic or cholesteric for a period of $\sim$ 3 msec as a result of an equimolar complex formed by hydrogen bonding with cholesterol. Only the last 5-6 (CH_2) groups in the lecithin tail and the tail of cholesterol have any degree of freedom of movement as a result of attractive forces. These groups are oriented by the electromagnetic field accompanying the tunneling electrons in spite of the relatively high viscosity of the liquid crystal. The quarternary nitrogen in the lecithin, chloride ions in the saline solution bathing the exterior of the axon, the negative ion in the interior and the negative dielectric anisotropy of the lecithin serve to promote dynamic scattering. As a result the information which the electrons carried in the field is impressed on the tails producing a liquid crystal pattern.



The information may be retrieved when a wave impinges on the pattern. The wave is reflected when it's instantaneous spatial electric field pattern is superposable on the pattern tails. If it is not superposable it continues without significant reflection loss.

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Introduction

In spite of the amount of study which has been given the subject of nerve conduction of impulses, the mechanism by which this is achieved is still not well understood. Nevertheless although insufficient hard facts are available, the outline of the procedures by which nerve conduction, storage and retrieval of information are conducted are beginning to emerge. The data which will be cited are to a certain extent controversial, but it is believed that together they form a coherent system in which uses have been found for all components of the molecules involved.

The axon has been identified as the element engaged in the conduction of electrical signals transmitted form the synapse. It is a fine tube having a wall thickness 70-100A and is immersed in a very dilute NaCl solution. The interior is filled with an aqueous solution containing K^+ and such anions as PO_4, SO_4, and a protein ion. Sodium salts are transported from the exterior to the interior and returned. When the walls of the axon are filled with Na^+'s and an impulse is emitted from the neurotransmitter, current flows. This occurs at intervals of 2 msec. The myelinated axon has been specifically spotlighted as the scene of the signal transmission but the exact details of the mechanism by which this is attained have not been elucidated. Myelin is composed of a mixture of cholesterol, (Figure 1), and lecithin, (Figure 2), arranged in closely packed alternate layers. Lecithin has been shown to be a transporter of ions across membranes but the method by which this occurs has not been described. Lecithin and cholesterol do not engage in any biochemical activities in the axon and are considered to be metabolically inert. The thesis which will be examined here is that in cholesterol and lecithin and their interactions will be found the key to the solution to these questions.

Ion Conduction. The part of lecithin most likely to be engaged in ion transport is the polar end extending from the quarternary nitrogen to the PO_4 group. This is also the part of the molecule which is immersed in the dilute salt solution surrounding the axon. The acyl oxygen atoms which are negatively charged have been reported previously to be capable of such activities. For example, Shah and Schulman (1) showed that the acyl oxygen of the PO_4 group of octadecyl and dicetyl phosphates could attract calicum ions by means of ion-dipole attraction and propel them into a space between two molecules of the phosphates (Figure 3).

Urry described a cyclic dodecapeptide antibiotic Valinomycin that effects the selective K^+ permeation of biologic membranes and lipid bilayers. The molecular model is shown in Figure 4 (2). "The K^+ is held in a central octahedral core, coordinated by six acyl oxygen moieties. The bipolar nature of the arrangement is seen by the hydrophobic side chains while the other side is hydrophilic and contains the nonhydrogen bonded acyl oxygens pointing into solution. The molecule would be expected to inter-act at a lipid-water interface. A conformational study derived a mechanism for ion transport as follows: the molecule sits at a membrane aqueous interface with its acyl oxygens directed like a three-fold bear trap into solution. As the acyl oxygens displace the ion's waters of hydration, it closes on the bare ion completely enveloping it, turning in the polar groups, and presenting a lipophilic exterior." Thus it is very likely that the acyl oxygens which form part of the PO_4 group imbedded in the lecithin act in a similiar

fashion as the acyl oxygen in the octadecyl phosphate and the cyclic dodecappeptide.

Relative postions of lecithin and cholesterol. In attempting to locate the positions of the materials with regard to each other we are guided by the work of Darke et al (3). They found that lecithin and cholesterol form an equimolar complex with a lifetime longer than about 3 msec, and that there is a hydrogen bond between the cholesterol OH and the lecithin phosphate group thus aiding in locating the molecules in the complex. The complex is bound by Van der Waals interactive forces between the steroid molecule and the first 10 methylene groups in each palmitic acid residue in the lecithin tail. This severely restricts the motions of this region of the chains while leaving the remaining part relatively free.

In Figure 5 is shown a schematic sketch of the cholesterol-lecithin complex. In 5a is shown the dipole-ion interaction between the acyl oxygen and the Na^+, the latter about to be released. The Na^+ is about at the site of the double bond of the cholesterol situated between carbons 5 and 6. In 5b the acyl oxygen has returned and hydrogen bonded to the cholesterol OH. Further information about the positions can be obtained form the voltage-time curve or the action potential curve. Figure 6 shows such a curve which has been normalized (4). The current is known to flow when the Na^+s fill the axon wall. This must occur immediately after the Na^+ has been released from the acyl oxygen and is in the area of carbons 5 and 6, since the voltage rises to a maximum at that time and then goes into a precipitous decline. The situation is now as is shown in Figure 7. In 7a two lecithin and two cholesterol molecules are side by side with the cholesterol molecules

located below the palmitoyl groups and 1-2 A off to the side. The PO_4 group is close to the OH group of the cholesterol. A Na^+ is in the corridor formed by the two cholesterol molecules. Current flows from one Na^+ to the other by means of the flow of electrons. The corridor in which the Na^+ is located is shown in 7b. Methyl groups and hydrogen atoms abound in the α and β locations so that the Na^+ is trapped within the confines of the corridor. The distribution of these groups is seen as fairly uniform in the sterochemical drawing of cholesterol (Fig. 1). The movement of K^+s is outside the scope of this paper.

Electrical conduction. The only problem with the model just drawn is that because of the distance between the Na^+s. $\sim$ 5 A, no current can flow by ordinary means. The ions are located in the area of the double bond with its conjugation and pi orbital but this is of little help, since there is no overlapping of pi orbitals and the resistance to flow is too great. Cholesterol has a resistance of $10^{10}\Omega$cm and is on the borderline between an insulator and semiconductor. The only known method by which an electron could travel this distance is by a method called tunneling and is reserved for superconductive materials only. Under these conditions the tunneling current would flow without any resistance (5). Let us examine the possibilities that the cholesterol corridor is indeed superconductive when the Na^+ is in it and at the position indicated. First, Ginzberg and Kirzhnits theorized about a superconductive sandwich model comprising a dielectric-metal-dielectric-metal composition which was layered in structure (6,7). Since then large numbers of such sandwiches have been synthesized with significantly enhanced transition temperatures. This model fits our description of the corridor since cholesterol is on the borderline between an

insulator and dielectric, and the sodium atom is metal. Second, Allender, Bray, and Bardeen quantified the sandwich model and showed that under certain conditions it could be superconductive even at room temperature and above (8). They postulated a sandwich model comprising alternate layers of semiconductors and metal. The layers were to be very thin, ~10 A, and there was to be intimate contact between the metal and semiconductor so that the former could tunnel into the gap region of the semiconductor and interact with the exiton The electrons near the Fermi surface are expected to tunnel into the gap a distance no greater than 5 A. Although it was shown that a maximum transition temperature, T_c of 800 K could be reached, it was believed that such a high value was unrealistic. They were unable, however to predict the proable T_c of any theoretical structure.

In order to pinpoint the probable T_c of such a sandwich, we refer to the "Little" theory that if an organic polymer had a conjugated main chain and side chains containing resonating structures with a positive charge up close to the main chain, the structure could be superconductive even at room temperatures and above (9). It takes little imagination to see that the Ginzberg and Little theories are quite similar if one examines them at right angles to each other. Although no one has yet synthesized a superconductor in accordance with Little's theory, his model has proved to be an incentive to many to attempt it. Our laboratory was also engaged in this program when our attention was called to the work of Halpern and Wolf (10-13). Summarizing their work, they claimed to have discovered a new type of superconductor designated as Type III. Type III comprised a superconducting state occuring in small randomly dispersed domains side by side with the bulk insulating state

in which the domains were dispersed. During a screening program they found experimentally that a homologous series of salts of cholates had transition temperatures ranging form 30 K for sodium dioxycholate (sodium dihydroxycholate) to 277 K for sodium cholanate. What they actually measured were frequency shifts of an oscillator circuit resulting from insertion of a sample into the coil of the tank circuit of an oscillator. This is a standard and sensitive technique for observing differential susceptibility of a sample (14) but is not considered definitive for superconductivity. Another phenomenon which they observed was that of diamagnetic levitation similar to the Meissner effect which is found only in superconductive materials.

Tinkham of Harvard who consulted on the project said after reviewing the work, "these experiments have revealed a phenomenon with sufficient resemblance to superconductivity in an organic system and with no other persuasive explanation yet in hand that further work to try to find the full origin of the effect would be very desirable." (Appendix A in reference 12). He pointed the way in stating, "The essence of superconductivity is the ability to carry an indefinately persistent current over macroscopic distances, a property that can only be established by a conduction such as trapped flux in a ring".

The materials which had been tested were the sodium salts of cholic, desoxycholic, lithocholic and cholanic acids. The composition of two others were inferred. The so called 'T_cs' (transition temperatures) were 7.5, 15, 30, 60, 130, and 277 K respectively. A study was made by us of their chemical and physical structures from the standpoint of superconductive

materials and it was found that there were inter-relationships which bolstered the case for the existence of superconductivity but which did not prove it. These included a relationship beteeen T_c and the isotope effect, the e/a (number of valence electrons/number of atoms (Figure 8), the lower critical magnetic field H_{c1}, Debye temperature θ_D (calculated) and the calculated specific heat, Cp. Inflection points were found in C_p-T curves at the experimentally found T_c for each material. The entire group represented a homologous series, each cholate salt differring from the next by a hydroxyl group (15-17).

Professor Deaver of the University of Virginia, using a superconducting magnetometer which measures static susceptibility, susceptibility and remanent magnetic moment as a function of temperature tested sodium cholate. By virtue of its method of operation magnetic fields which are induced around each particle coalesce into larger fields until there is one large field. Trapped flux appeared at 4 K upon the application of current and remained after it was turned off and the temperature was allowed to rise. The flux decreased as the temperature rose, took a sharp drop at 30 K, and finally disappeared at 60 K. Magnetic measurements were made every 15 minutes and a discontinuity was obtained between 28 and 30 K as would be expected if it were superconductive. In all of the reported tests the signals was very low (10). The possibility that the material contained magnetic impurities was checked and none were found. We now attribute the low level of the signal to a number of factors. First, the steriod nucleus is closer to an insulator than a semiconductor since it has no conjugation. Secondly, the Na^+ is off center in the molecule so that it barely qualifies

as a sandwich. Finally, the sample was a random mixture of anisotropic crystals and that if it had been a single crystal and was tested at the optimum location a much stronger signal would have been received.

The significance of the discussion of the cholates is two-fold. First is the obvious resemblance between cholesterol and cholates. They both have the same steroid nucleus and similar tails. The cholesterol tail is longer than that of the cholates and is purely hydrocarbon compared to the tail of the cholates which ends in a carboxyl group. The cholates crystallize so that ionizable sodium atoms fit under parts of nearly molecules so that in effect a Ginzberg sandwich is formed. Their nucleus has no conjugation and hence no pi orbitals to enhance their electrical conductivity like cholesterol. (Figure 8).

Matthias through the years used as a tool to discover high T_c superconductors, the relationship between T_c and e/a (19). When such a curve is drawn for the homologous series of the cholates, and is extrapolated upwards to a higher temperature, a T_c of 500 K is obtained for an e/a of 2.16 which is the e/a value for cholesterol. Cholesterol is not a cholate but it is believed sufficiently close to yield a figure which is highly significant. A plot of calculated C_p vs T for the sodium salt of cholesterol oxide shows an inflection at 350 K. This relationship is considered almost definitive in the superconductive field but must be accompanied by a sharp spike which can only be obtained experimentally. Similarly, the sodium salt of 5 β cholan 24-ol also shows an inflection at 350 K. The latter salt is sodium cholanate

with an oxygen in the carboxylic group removed and replaced by two hydrogen atoms. This has the effect of decreasing the value of its e/a. Both materials should be superconductive at room temperature and attempts are presently being made to grow their single crystals for testing.

The e/a value of dipalmitoyl lecithin is 2.34. When its acyl oxygen complexes with the OH of cholesterol by hydrogen bonding for about 3 msec, a single compound is formed momentarily with a combined e/a value of 2.28. Even if such a structure had the right crystalline structure it would go superconductive only at $\sim$150 K. Therefore complexing has the effect of eliminating electrical conductivity and is the cause for the go-no-go-type of conduction found in nerve tissue.

Accompanying the current or flow of electrons is a magnetic field perpendicular to the line of flow. This has the effect of repelling and deflecting ions away from the acyl oxygen of the PO_4 group which they will have attracted, thus limiting the number of Na^+'s in the corridor to one. The Na^+ in the corridor is discharged into the interior of the axon. In the interior of the axon, other lecithin molecules with their hydrophilic heads facing in the water, transport the Na^+ back to the exterior.

Storage of information. The magnetic field accompanying the electrons carries a message which is in the form of a waveshape whose spectrum is relatively complicated. The curve depicted in figure 6 is a simplification of the waveform and represents a combination of many waveforms

involved in the signal. Probably hundreds of electrons are required to carry information such as the appearance of an object. The mechanism used to store the data is the same one which is used in memory devices using liquid crystals and similar to the magnetic memory banks of computers. Liquid crystals are affected by magnetic fields and the molecules of which they consist are oriented by them (Figure 10). The magnetic field couples with portions of both cholesterol and lecithin because of their liquid crystal characteristics and orients them. Since the tail of cholesterol and part of the tail of lecithin are the only parts of the two molecules which have any significant freedom of movement it is probably these which are oriented. Actually neither molecule is a liquid crystal but when hydrogen bonded they could easily become one. Although cholesterol is non-mesomorphic it has been considered potentially so since even cholesteryl chloride gives a monotropic mesophase and it is possible that hydrogen bonding increases the intermolecular cohesion and lengthens the molecule sufficently (20).

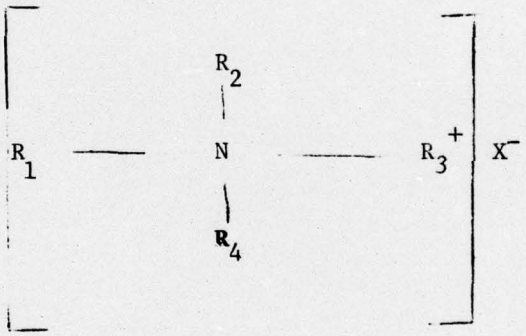
An interesting observation may have reference to the moment when the phase change occured. The action potential has been found to be accompanied by a transient change in the birefringence of the nerve., i.e. its ability to affect the passage of light. The effect is extremely small and the measured light changes in intensity only slightly. The change occurs in or near the cell membrane and is characterestic of the scattering of light produced in a nematic liquid crystal when exposed to a magnetic field.

When lecithin molecules are equilibrated with salt solution as exists in the axon they form liquid crystals of the smectic mesophase type, composed of lipid lamellae separated by aqueous layers (21, 22). When hydrogen bonded with cholesterol it may be converted to either the nematic or cholestric type. Cholesteryl palmitate is cholesteric and it is very similar in structure to the hydrogen bonded complex (23).

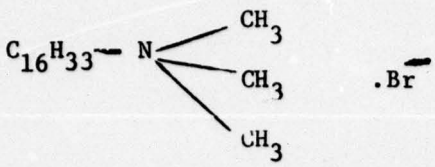
Although cholesteric and nematic liquid crystals are easily oriented by magnetic fields, smectic types are very viscous and are not readily moved. In this case the molecules are packed so tightly together that only their tails are mobile. The cholesterol tail and 5-6 of the last groups of the lecithin tail are mobile as shown by ESR investigations (3,23). Quantitative interpretation of the results suffered from the drawback that the presence of a magnetic field in the equipment might have caused the movement of the tails. If so, movement of the tails in a magnetic field was shown to be possible, but only by a very strong field, stronger than the one accompanying the flow of electrons in the axon.

The tails are hydrocarbon chains containing no charged atoms or dipoles with the possible exception of the double oxygen and hence can not be strongly affected by the magnetic field. They can, however, be affected by dynamic scattering or flow alignment. This may be defined as the phenomenon that results when charge in a transit through nematic material of negative dielectric anisotropy generates hydrodynamic shear forces leading to the turbulent flow. Molecules that have their dipole moment

operating across the molecular axis are said to posses negative dielectric anisotropy (NDA). Lecithin should have NDA since it has dipoles in both the head and tails. The flow alignment is negligable in the part of the tail held virtually motionless by Van der Walls forces to the steriod nucleus but could be considerable in the more freer end part. The greatest effect could arise from the hydromagnetic force accruing from the presence of the double bonded oxygen in the tail. It has been found that halides of quarternary nitrogen compounds when added to nematic or a mixture of nematic and cholesteric liquid crystals enhance their dynamic scattering ability (24). Alkyl halides when added in very small quantities to nematic liquid crystals of the Schiff base type also have such an effect (25). In the former case one of the aditives specified is



where R_1, R_2 , R_3, and R_4 represent alkyl or aralkyl groups having not more than 20 carbon atoms and phenyl groups, and X^- represents a halogen which could be chlorine, iodine, etc.. If R_1 represents a palmitic acid residue and the other R's are CH_3 groups the resemblance to dipalmitoyl lecithin is startling. Hexadecyltrimethylammonium bromide having the structure



is also similar in appearance to lecithin with the exception of the double tail and PO_4 group. The inference is that lecithin also doubles as a dynamic scattering agent when the Cl^- in the water is attracted to the N^+ site as the electric balance is upset by the movement of the Na^+ into the corridor. A long range effect is also possible when the situation is examined from the standpoint of ion concentration and membrane potential. When the resting nerve potential exists there are large numbers of anions in the interior of the axon (26). These may aid the dynamic scattering through a hydrodynamic effect by the tail carboxylic oxygen during this phase. When the molecules are complexed, no current flows and they constitute a liquid crystal complex probably of the nematic type and is capable of dynamic scattering although there is no magnetic field present. When they are not complexed, current flows, a magnetic field exists but no liquid crystal structure is present. The model described therefore would not work unless there was a delayed action of the effects of the dynamic scattering. There is such a delay as described by Toriyama (24) and is due to the requirement for time for the magnetohydrodynamic effect to take place. For the specific case where 0.2% by weight of the halides of N^+ compounds were added this was 2 msec and is called 'rise time' (a time from the application of the voltage until the contrast reaches 90% of saturation value). This is in the order of magnitude of the 3 msec complex life time

of the lecithin-cholesterol complex and the 2 msec action potential time. Examining the conditions in the axon (4) and patent (24) it is seen that in the axon the frequency has a range of 400-1250 Hz compared to 3-2000 Hz in the invention, and the emf in the axon (assumming a 100A wall thickness and 50-70 mv threshhold voltage) has a range of 50,000-70,000 v/cm compared to 1,000-40,000 v/cm in the invention. Thus the operating conditions of the two systems are comparable.

Retrieval of information. It was shown earlier that although hydrated lecithin was a smectic liquid crystal it complexed with cholesterol which could have imparted to it the properties of the nematic or cholesteric type for the lifetime of the complex. Since the lecithin and cholesterol molecules are so tightly packed it is a matter of academic interest only which type it was, outside of the advantage of reduction of viscosity which is obtained as a result. The scattered state in which those portions of the molecules which could move are found, contain the impressed information in the various angles and orientations they have taken as a result of the magnetic field waveform. This state is not amenable to any mathematic analysis. An interesting work in which an analysis is made of cholesteric or chiral nematic liquid crystals with regard to their reflective properties is applicable to our problem (27). "The wave equation is solved for the case of waves propagating parallel to the axis z of an ideal helix, which, for any plane z = constant, is characterized by two indices of refraction. Four solutions

are obtained, two corresponding to waves traveling in the positive z-direction. One of the two waves propagating in each direction is found to be strongly reflected when its wavelength becomes comparable to the pitch of the helix. The polarization vectors of the eigenmodes are determined, and it is shown that the strongly reflected wave is the one whose instantaneous spatial electric field pattern is a helix that is superposable upon the cholesteric or chiral nematic helix. The other wave is found to propagate without significant reflection loss, independent of it wavelength." In a discussion with the author he stated that the analysis would probably hold for a smectic or any other liquid crystal type providing the formula for the distribution of the molecules could be written. Thus a searching wave from another part of the brain or nervous system is provided with a simple method of extracting information deposited in the axon.

Discussion

The proposed theory takes into account every detail of the structures of lecithin and cholesterol. In cholesterol the reasons for the following were described: rectangular almost flat shape, side chains (H and CH_3), relative number of C, H and O atoms, hydroxyl group, double bond, and the tail. In lecithin, the quarternary nitrogen group, embedded PO_4 group with acyl oxygens, the tails and the oxygen in the carboxylic residue in the tails all have functions. The purpose for the complexing, method of electrical conductivity, doubling of the molecules as liquid crystals, and the reason why they are in the position they occupy are explained. The

molecules appear to have envolved into their present design for the express purposes which have been discussed here. While information in some of the referenced materials have strong experimental foundations, others such as the assumed superconductivity of the corridor can be considered highly controversial. Nevertheless it is this working hypothesis which opened the door to clarification of all the structural elements. It is evident that further work should be expended along the lines indicated.

Examination of the methods by which people learn show that they mesh with the thesis of this study. For example we learn by rote indicating that it is difficult to impress the pattern of the waveform on the liquid crystal in spite of assistance from dynamic scattering. This can be considered a positive survial factor. Once learned, data cannot be unlearned. Correct and incorrect information exist side by side. We do, however, forget information which we do not use, indicating that there must be a gradual erosion of the pattern with time due to external effects. People also learn by association of data which they already possess. This is in agreement with the model since all that is required to learn is a new associative word or group of words linking the patterns together. Both cholesterol and lecithin are slightly soluble in alcohol. This could explain the gradual loss of memory and senility of alcholics since greater freedom of movement to solvation would disrupt the memory pattern. The use of electric shock treatment also causes loss of memory. This coincides with the observed threshhold voltage of liquid crystasl which forces them to move in strong magnetic fields.

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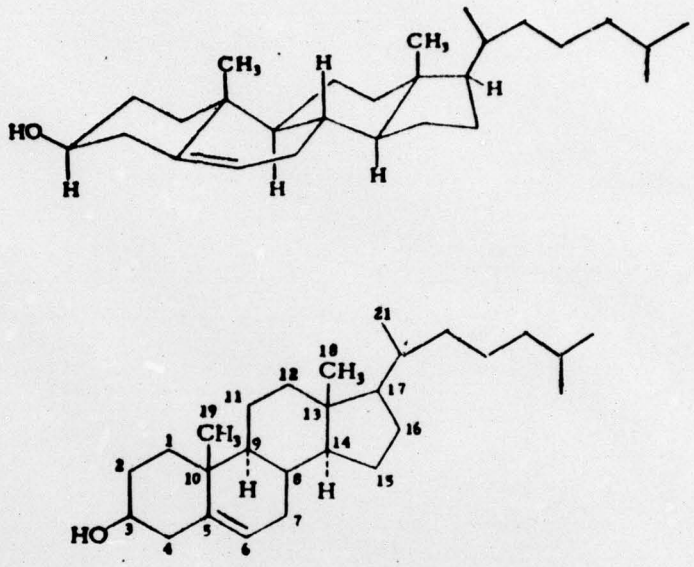


Figure 1. Stereochemical and Numbering System of Cholesterol

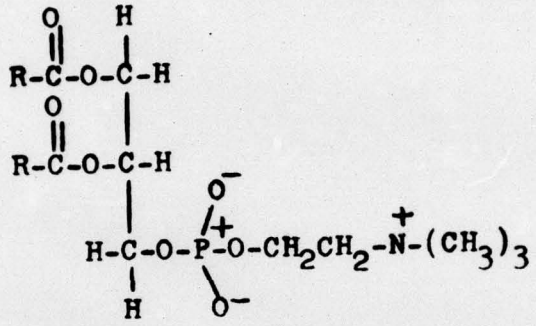


Figure 2. Structural Formula of Dipalmitoyl Lecithin Where R is a Palmitic Acid Residue.

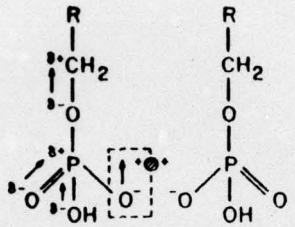


Figure 3. Octadecyl phosphate in monolayer showing dipole ion attraction (Ref 1).

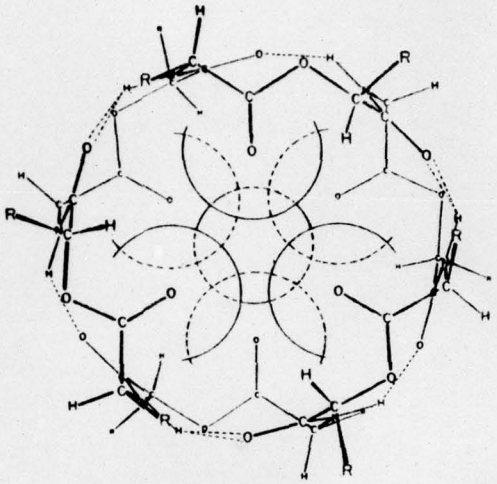


Figure 4. Conformation of Cluster of Cyclic Dodecapeptides Forming Valinomycin-K^+ Complex by Dipole-Ion Interaction Between Acyl Oxygen and K^+ (2).

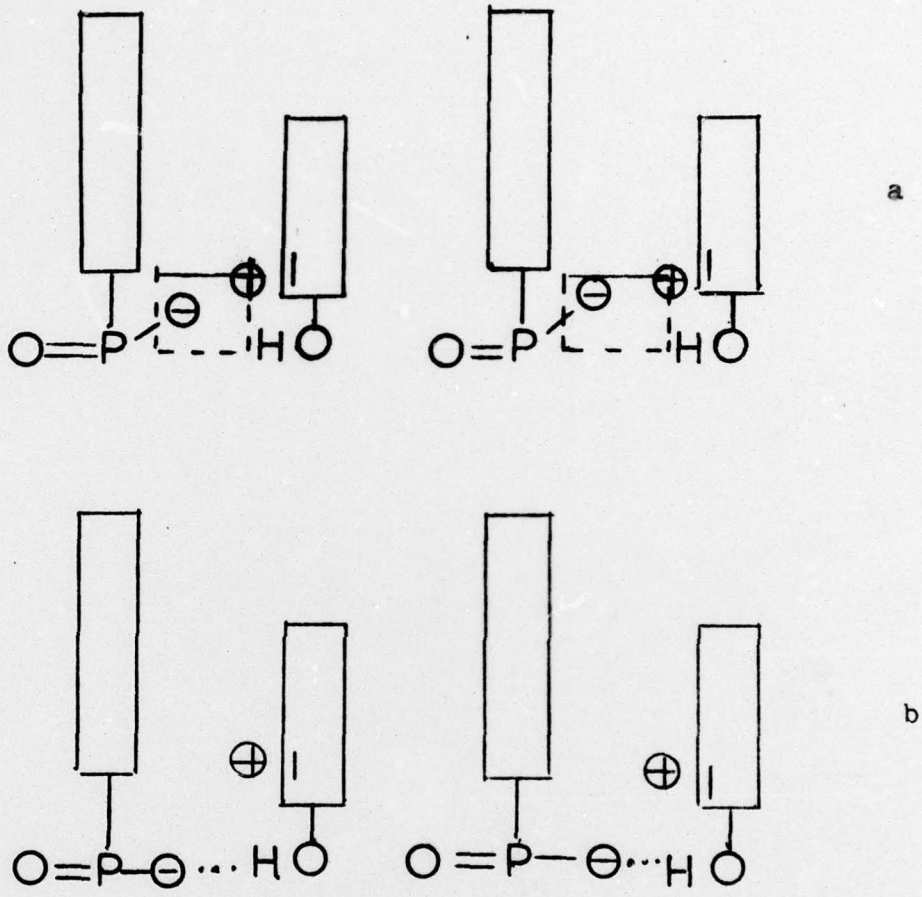


Figure 5. Schematic diagram of cholesterol-lecithin complex showing (a) dipole-ion attraction between acyl oxygen of phosphate group and Na^+: (b) hydrogen bonding between acyl oxygen with OH group of cholesterol after Na^+ was released and acyl oxygen retracted.

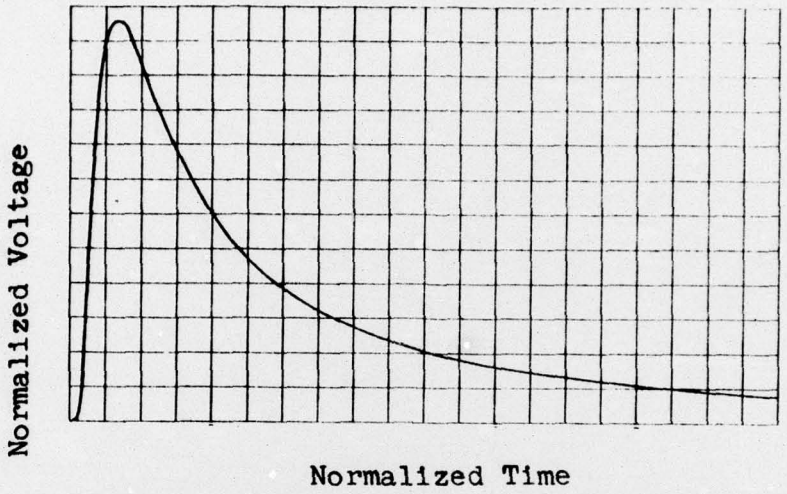


Figure 6. Sketch of smoothed action-potential waveshape that is observed in vivo (Ref 4)

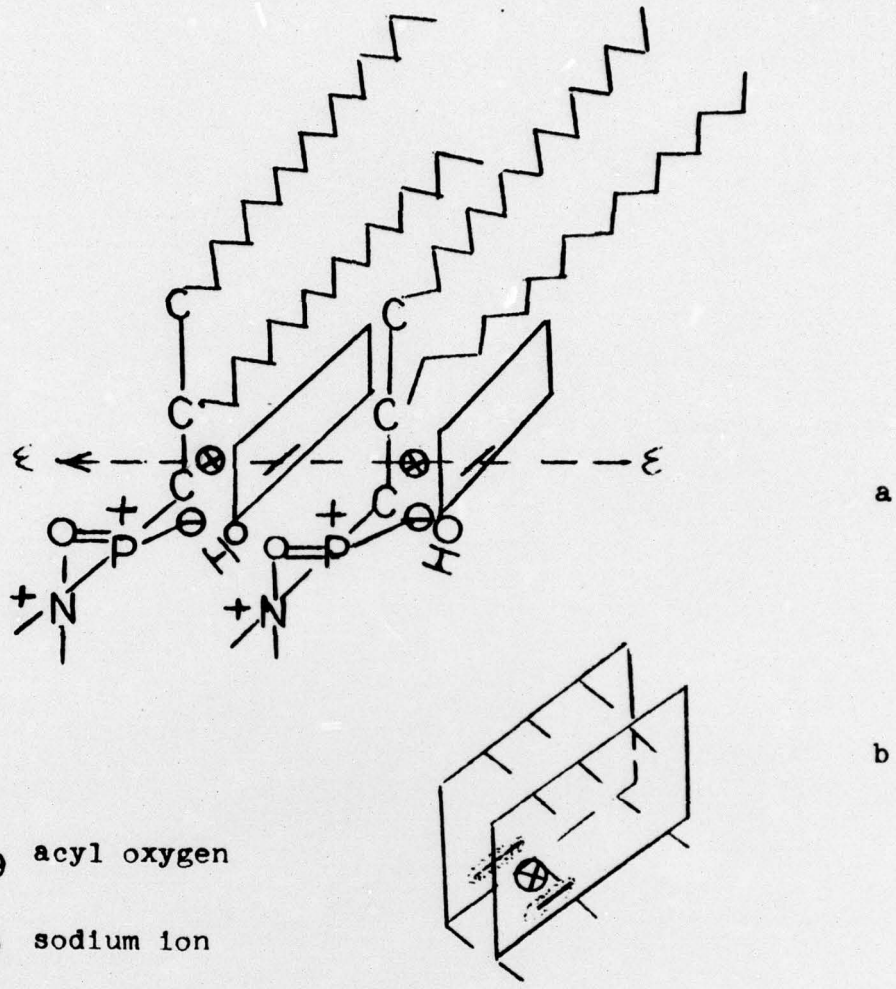
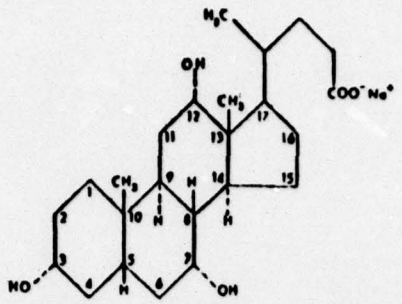


Figure 7. Sketch showing (a) relative positions of lecithin and cholesterol where the acyl oxygen has just released a sodium ion into a corridor formed by two parallel molecules of cholesterol. The electron is shown tunneling through the pi cloud; (b) a sketch showing the cholesterol corridor and CH_3 and H side chains forming a cage.



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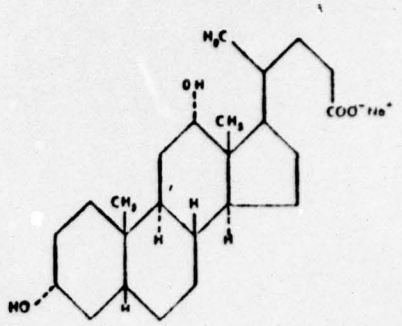

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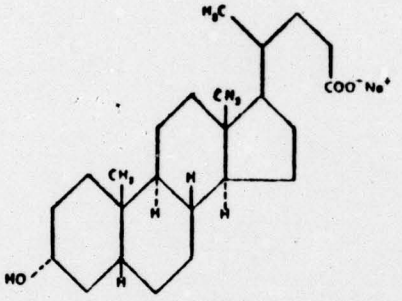

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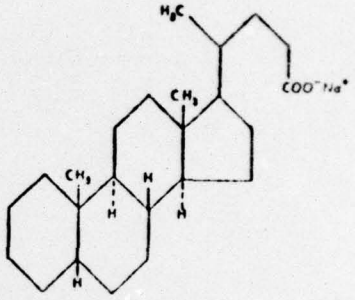

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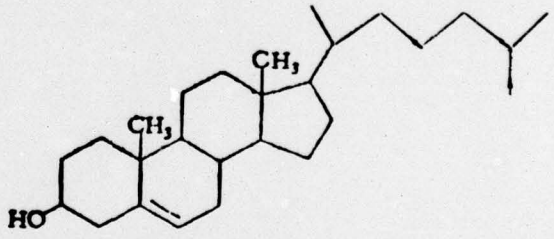

e

Figure 8. Structural formulas of (a) sodium cholate; (b) sodium desoxycholate; (c) sodium lithocholate: (d) sodium cholanate; and cholesterol

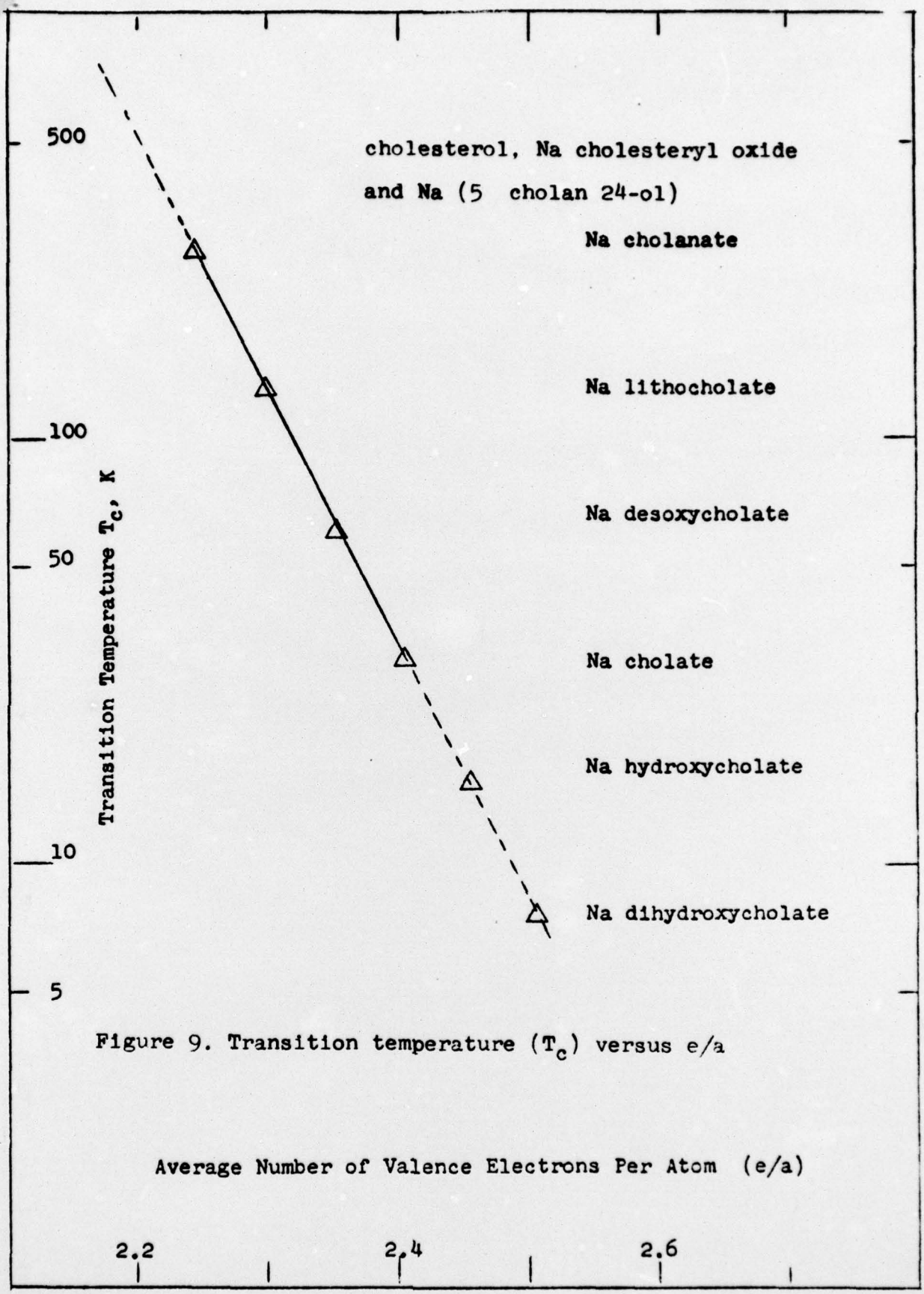

Figure 9. Transition temperature (T_c) versus e/a

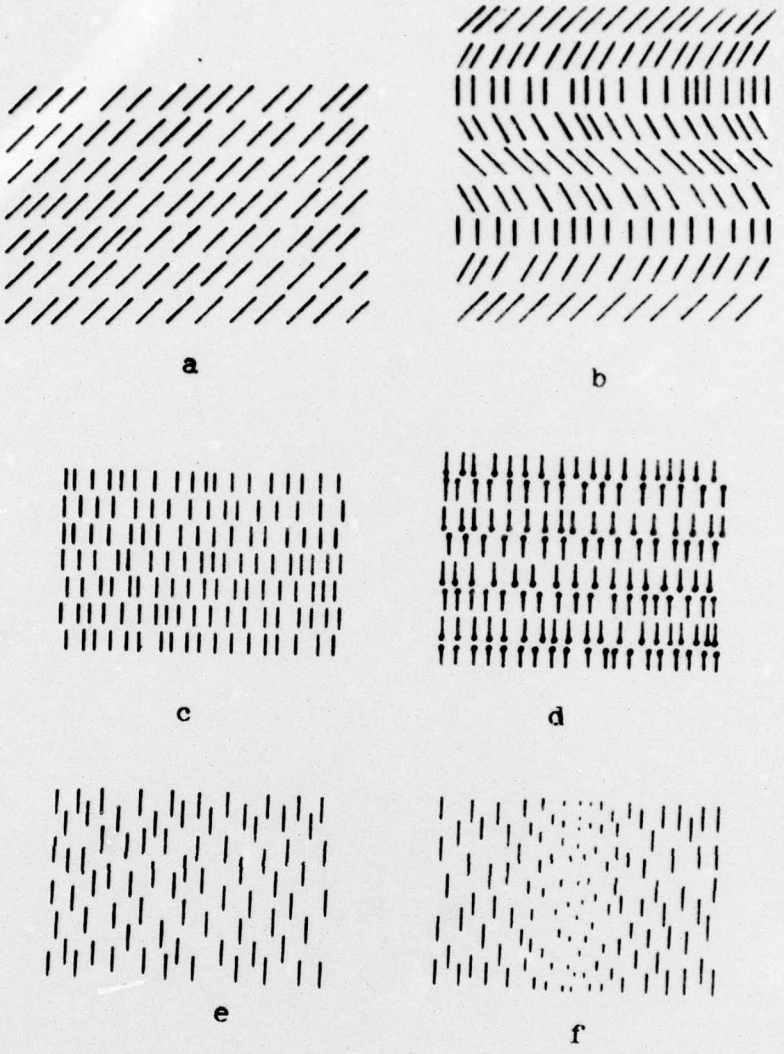

Figure 10. Schematic structures of smectic, nematic, and cholesteric liquid crystals. The lines represent molecules and represent the preferred orientations. First group represents biaxial smectic liquid crystals with tilted unstructured layers. The second group (c, d) are smectic liquid crystals with $D_{\infty h}$ symmetry. The third group shows nematic (e) and cholesteric liquid crystals (f).

REPORT DOCUMENTATION PAGE

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electromagnetic fields, nerve electrical conduction; high temperature electrical conductivity; Ginzbers sandwich; exiton mechanism; smectic liquid crystal; dynamic scattering; lecithin-cholesterol interactions; axon electrical conductivity; nematic liquid crystals; dipole ion attraction.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Nerve Electrical Conduction Storage and Retrieval of Information A Theory (1). Lecithin and cholesterol which form closely packed arrays in the wall of the axon in nerve is identified as the location for electrical conduction, information storage and retrieval. The complex of lecithin and cholesterol is seen as a machine concerned with transporting sodium ions into a corridor comprising two cholesterol molecules. Based on considerations from two approaches, the cholesterol-sodium-cholesterol sandwich becomes superconductive in accordance with Ginzbergs' theory as

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20. quantified by Bardeen and co-workers, and electrons tunnel from one sandwich to another.

Hydrated lecithin which is a smectic liquid crystal may become nematic or cholesteric for a period of 3 msec as a result of an equimolar complex formed by hydrogen bonding with cholesterol. Only the last 5-6 (CH_2) groups in the lecithin tail and the tail of cholesterol have any degree of freedom of movement as a result of attractive forces. These groups are oriented by the electromagnetic field accompanying the tunneling electrons in spite of the relatively high viscosity of the liquid crystal. The quarternary nitrogen in the lecithin, chloride ions in the saline solution bathing the exterior of the axon, the negative ion in the interior and the negative dielectric anisotropy of the lecithin serve to promote dynamic scattering. As a result, the information which the electrons carried in the field is impressed on the tails producing a liquid crystal pattern. The information may be retrieved when a wave impinges on the pattern. The wave is reflected when it's instantaneous spatial electric field pattern is superposable on the pattern tails. If it is not superposable it continues without significant reflection loss.